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"ITHACUS" - A NEW CONCEPT OF INTER-CONTINENTAL BALLISTIC TRANSPORT (ICBT)

by

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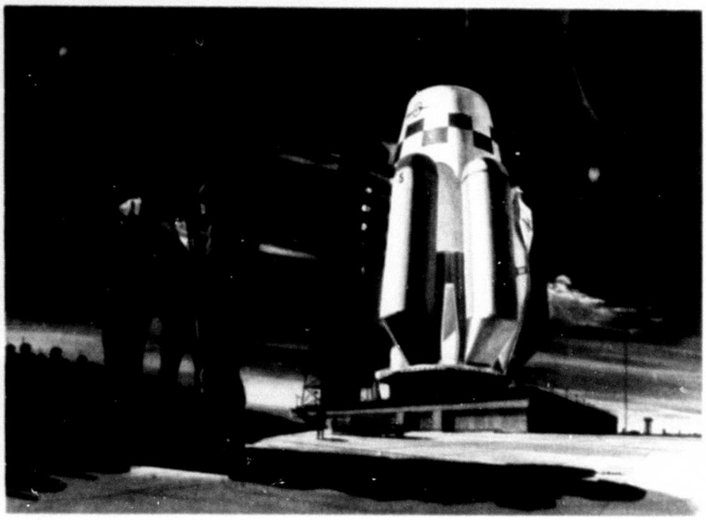
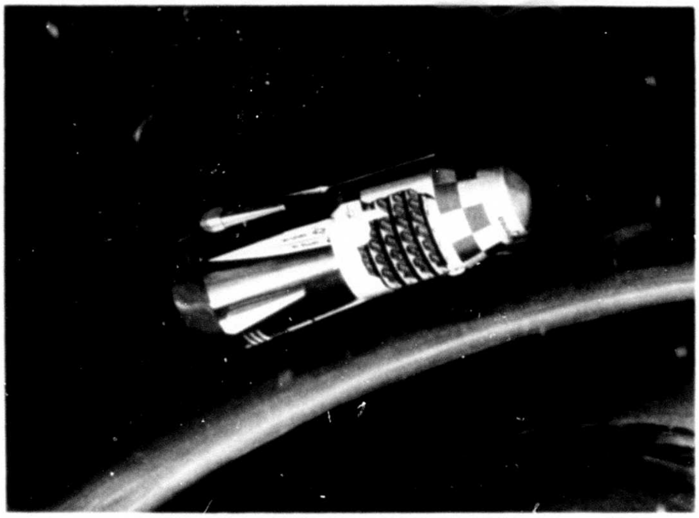
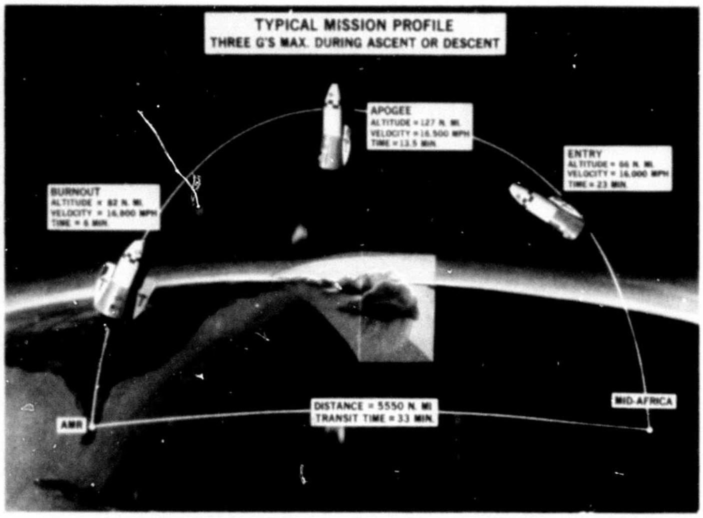
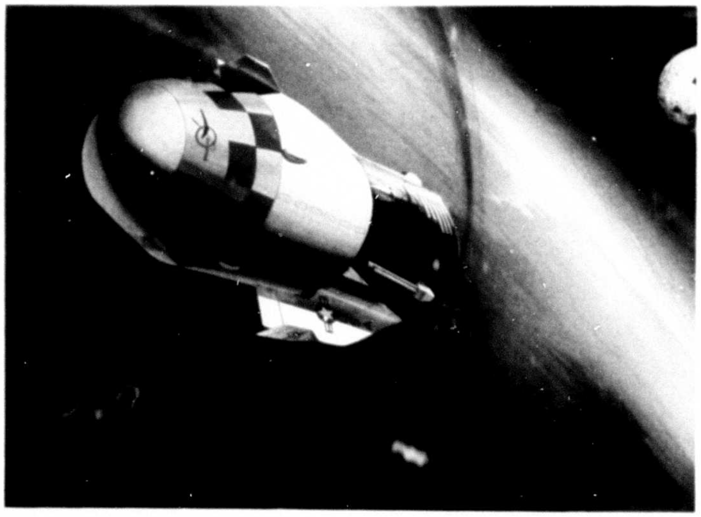
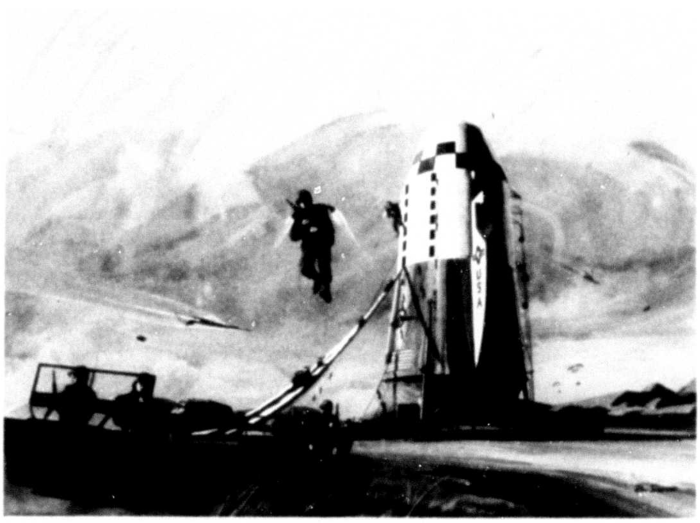





TYPICAL MISSION PROFILE
THREE G'S MAX. DURING ASCENT OR DESCENT
APOGEE
ALTITUDE = 127 N. MI.
VELOCITY = 16,500 MPH
TIME = 13.5 MIN.
BURNOUT
ALTITUDE = 82 N. MI.
VELOCITY = 16,000 MPH
ENTRY
VELOCITY = 16,000 MPH
TIME = 23 MIN.
AMR
DISTANCE = 5550 N. MI.
TRANSIT TIME = 33 MIN.
MID-AFRICA





"ITHACUS" - A NEW CONCEPT OF INTER CONTINENTAL BALLISTIC TRANSPORT (ICBT)

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Abstract

During "Operation Big Lift," in October 1963, 15,700 troops and 500 tons of cargo were transported in 235 missions in the largest long-range U.S. airborne peace-time exercise attempted to date. Turbojet and piston-engine aircraft traveled the 5,600-mile route between a series of Texas airfields and ten Western Europe airfields in Germany, France, Spain, Scotland, and England. The entire operation was accomplished, with enormous success, in 63 hours.

As a wartime strategic operation, however, such a method for movement of troops to potential battlegrounds overseas would be cause for profound dismay. The reliance on perfectly conditioned 10,000-foot landing runways, operational landing aids, stand-by support equipment, and ideal weather conditions provide a basis for due apprehension. As long as military transport systems must depend upon prepared landing surfaces, easily detected and destroyed by enemy gunfire or missiles, the entire concept of such troop movement is rendered completely impractical under hostile conditions.

This paper describes a concept for a rocket-powered troop transport which may potentially evolve from the reusable booster of tomorrow. The VTOL rocket concept, however, is based on the premise that the initial reusable booster, sized for a payload of approximately 800,000 pounds-to-orbit, is also designed for land recovery. The global transport derivative vehicle would then be correctly sized for ballistic delivery of a full U.S. Marine Corps battalion (1,200 troops) or 132 tons of military equipment at average speeds of 17,000 mph to any point on earth within 45 minutes. On a typical mission for quelling a hypothetical brush-fire, the manned rocket carrier, equipped with a troop compartment as a payload, would travel from the Atlantic Missile Range to the middle of Africa (a distance of 5,600 miles) in 33 minutes, without depending on a previously prepared landing strip for successful mission accomplishment. By throttling of the engines, the troops (reclining on couches installed on six decks) would not be subjected to any more than 3 g's during the 6 minutes of vertical ascent to the 127 nautical mile apogee. Fins would be adapted to the booster version in order to restrict the decelerations, during 12 minutes of controlled atmospheric entry, to a maximum of 3 g's. During entry, the ballistic transport would glide at a 52 degree angle of attack, until the horizontal velocity is nullified. Prior to a soft landing, the propulsion system would cancel any vertical velocity component and allow the vehicle to hover and translate horizontally for pin-pointing the landing site. Vertical touch-down would then be accomplished on four extensible legs in a manner similar to the Apollo method of landing on the moon.

Introduction

Perhaps the era of the brute-force approach to space flight, which began with Sputnik, on October 5, 1957, may find itself superseded within 3 or 4 years by the age of the reusable booster. If such a reusable carrier, which could be operational by 1975, were soon subjected to a national funding commitment, it is not premature to speculate on the most attractive design characteristics which should be incorporated into this Post-Saturn vehicle. Booster reusability is gradually finding acceptance by even the most reluctant of technical skeptics. However, reuse alone, of this hypothetical transport, is not a sufficient goal. The paramount design objective should be directed toward maximum mission flexibility. This premise, which implies that land recovery be mandatory, would suggest the corollary of single-stage-to-orbit capability, in order to minimize the problems of recovering the entire booster from orbit near the launch site. Clearly, incorporation of all these recommended features would necessitate a radical departure from conventional booster design and would result in significantly increased engineering complexity and a high degree of technical sophistication. It does not appear, however, that any proverbial "technological break-throughs" would be required before such a "flying machine" could materialize. A straightforward permutation of such a reusable booster would possess inherent potential applications for global transport systems which are staggering to contemplate.

A transport, which can operate in the manner described by this paper, rocketing immense battle units to distant war zones at speeds of 17,000 mph, could evolve into the most revolutionary advance in military transportation since the airplane. Its impact on military strategy could modernize traditional Marine Corps techniques by replacing conventional sea power and amphibious operations. Logistics problems of the U.S. Armed Forces would be facilitated by the delivery of supplies and equipment to anywhere in the world in a fraction of the time required by even the supersonic transport, assuming that a prepared landing strip were available for its military operations. The vehicle concept defined in this paper has been termed ITHACUS.

Conceptual Vehicle Definition

Before this paper attempts to describe the ITHACUS military transport, perhaps a brief explanation of its hypothetical predecessor, the ROMBUS reusable booster concept, is necessitated. The latter vehicle is extensively defined in the first three references of the bibliography. It should be emphasized that this paper does not present the

ITHACUS troop transport as an independent vehicle recommendation but as an extrapolation to a potential application for a land-recovered orbit booster.

The ROMBUS conceptual vehicle (see Figure 1) uses a plug-nozzle engine of altitude-compensating design. This type of engine is a necessity since a conventional bell nozzle would not survive the aerodynamic heating during a stable base-first recovery. Recovering the vehicle in this attitude will allow use of the same engines (employed during boost) to provide retro-thrust for terminal velocity cancellation; allowing the vehicle to gradually descend to a soft landing on earth. Because the engine's plug nozzle is regeneratively cooled during ascent, the same cooling system would maintain the temperature of the entry body within tolerable limits during peak aerodynamic heating prior to landing. The earth touch-down maneuver, on four extensible legs, will utilize the technology which will be developed for the Apollo manned lunar landing.

The high-drag atmospheric entry body resembles a truncated cone with the isentropic plug nozzle of the engine forming its blunt re-entry nose. A conic section contains an internal spherical LO_2 tank, with a cylindrical four-man crew compartment installed near the upper edge of the truncated cone. Eight detachable (parachute-recovered) LH_2 tanks are strapped around the tapered centerbody during boost. These cylindrical LH_2 tanks provide aerodynamic "shadowing" for the two fins during vertical (ballistic) ascent through turbulent atmosphere. The two fins (with lateral control surfaces) are attached to the exterior of the centerbody providing lifting maneuverability for pin-pointing the landing destination and for reducing the re-entry decelerations after the expendable LH_2 tanks have been depleted and jettisoned.

highly-trained and conditioned astronauts, but would prove to be excessive for fighting men, even in the best physical condition. Therefore, a 3-g limit during boost and entry was adopted as a physiological criterion.

In addition to the physical differences of the two vehicles, the material (titanium), used for construction of the ROMBUS reusable booster, would not withstand the increased temperatures, of the ITHACUS re-entry mode, when the underside of the vehicle is subjected to a higher heat flux; therefore, it appears that a type of stainless steel would replace the structural material of the reusable booster, at least on the underside of the vehicle.

The "parent" ROMBUS reusable booster weighs 14 million pounds at lift-off. The same gross weight was adopted for the hypothetical ITHACUS global transport; therefore, the same advanced engines, which would have to be developed for ROMBUS, would be directly applicable to the ITHACUS version of the vehicle. Since ROMBUS required throttleability (or thrust modulation of engines) for its primary mode of operation, the ITHACUS flight profile was based on the same propulsion system characteristics. By sheer coincidence, the Post-Saturn booster size (with a lift-off thrust of 18 million pounds) will provide an ITHACUS-type derivative with a capability of transporting a full battalion of troops to a maximum required range of 7,600 nautical miles, assuming that a launch site is available on each coastline of the Continental United States. On missions where the 264,000 pounds of useful payload would be comprised of both troops and cargo, part of this cargo can be carried within compartments installed in the unused volume above the spherical liquid oxygen tank.

ROMBUS VEHICLE CONFIGURATION

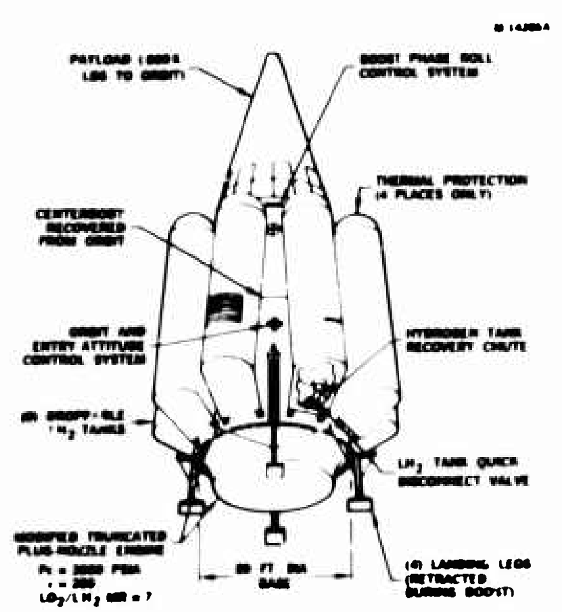

FIGURE 1

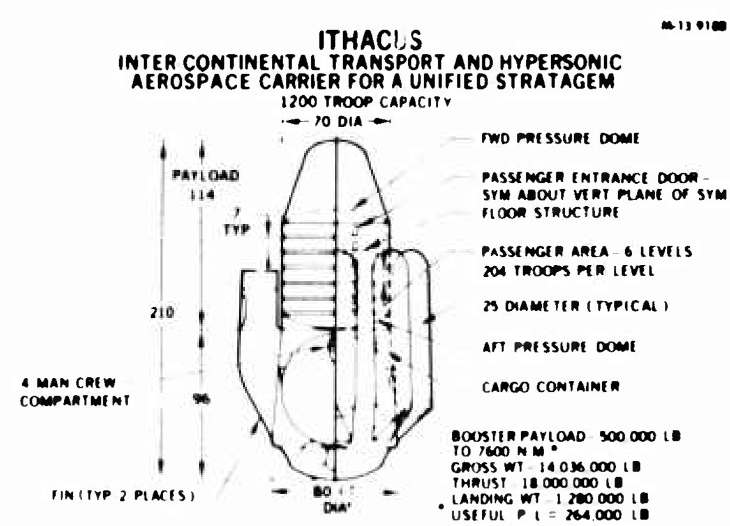

FIGURE 2

By comparing Figure 2 with the previous figure, it can be seen that the major distinction between the ITHACUS version and the reusable booster version lies in the payload section configuration (which contains the troop compartment) and the addition of two fins shown between the liquid hydrogen tanks. The fins are necessary in order to restrict the reentry decelerations to a maximum of 3 g's. Without a lifting entry, ballistic decelerations might reach 10 or 11 g's, which may be acceptable for

The table of Figure 3 presents the principal design parameters for the ITHACUS troop transport. The effective mass fraction for this vehicle is significantly less than that of its reusable booster counterpart. The designation "effective" indicates that the weight-reduction benefits attendant with LH_2 tank disposal during flight have been included in the performance calculations. The effective mass fraction of ITHACUS is reduced to allow for 1) the added structural weight of its fins, 2) the

additional weight of the stainless steel which replaces the titanium structure on the underside of the vehicle, 3) the added LH_2 required for cooling the blunt nose during entry, 4) the increased retro-propellant required and 5) for the added strength required of the four landing legs and attach fittings. The ITHACUS vehicle lands with payload attached; whereas, the ROMBUS reusable booster separates its payload in orbit. Only the ROMBUS centerbody (without payload) is landed.

The ITHACUS transport version, although not acquiring orbit, requires some 800 fps in excess of orbital velocity for its balistic mission due to the increased gravity losses during vertical ascent. Nevertheless, since the magnitude of the two mission velocity requirements are grossly comparable, this factor, more than any other, would explain why a booster, initially sized for a single-stage-to-orbit mission, can be directly adapted to a ballistic global transport mission.

GLOBAL TRANSPORT PARAMETERS

	ITHACUS MILITARY TRANSPORT (P/L = 500 K. LB.* TO 7600 N. MI. RANGE)
MAX. THRUST (LB.)	18 M
THRUST-TO-WT. RATIO (T/W)	1.25**
MAX. LIFT-OFF WT. (LB.)	14 M
USABLE PROPELLANT (LB.)	12 M
EFF. MASS FRACT. (-)	.912
VAC. SPECIFIC IMPULSE (SEC.)	455
NOZZLE EXPANSION RATIO (-)	200
IMPULSIVE VELOCITY (F.P.S.)	30.9K
LANDING WEIGHT (LB.)	1.28M
OVERALL LENGTH (FT.)	210
PAYLOAD DIA. (FT.)	70

**CONSTANT FOR ALL MISSION RANGES AND % PROP LOADING

LO_2/LH_2 PROPELLANT SYSTEM

P_C = 3000 PSI, M.R. (O/F) = 7/1

*264 K LB. (132 TONS) USEFUL PAYLOAD

FIGURE 3

Figure 4 illustrates the pressurized four-man crew compartment, which would be installed within the booster centerbody, above the spherical liquid oxygen tank. The crew would enter this compartment by way of the external door and access ramp, then through the airlock.

The airlock is incorporated into the crew compartment, for mission flexibility, allowing the crew to participate in orbital rendezvous operations outside the ROMBUS (antecedent) vehicle. Since the 10,000 pounds of this pressurized compartment was not included in the initial weight breakdown for the ROMBUS orbital booster, it has been incorporated into the weight estimate for the ITHACUS vehicle, as tabulated in Figure 9.

Three solid propellant motors provide emergency escape provisions for the crew during aborted flight; however, it should be noted that this capability will only be used during cargo transport missions or during the flight test/development phase of the program. During troop transport operations, the entire vehicle will have complete abort (water-recovery) capability.

Two heat shields are provided above and below the external portion of the crew compartment to protect the windows from excessive heating during ascent or entry. The lower heat shield is jettisoned after entry, just prior to the terminal retro-phase. The upper heat shield, which is necessary for the ascent phase, is only jettisoned prior to an emergency abort of the crew capsule. In the event of such an abort, two stabilizing fins are provided on the side of the crew compartment to prevent the capsule from tumbling during operation of the solid-motor escape rockets. The weight of ablatant necessary for thermal protection of the fins and the compartment underside has not yet been assessed.

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ITHACUS-ROMBUS
4 MAN CREW COMPARTMENT

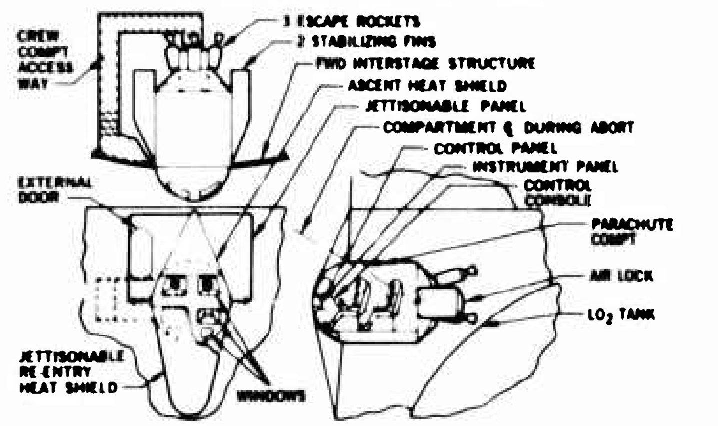

FIGURE 4

Figure 5 depicts a typical low-altitude emergency escape condition and illustrates the front panel being jettisoned along with the ascent heat shield. Prior to ejection, the centerline of the entire capsule is automatically rotated upward approximately 30 degrees. The escape rockets then will thrust in an upward direction (as well as outboard), away from the jeopardized vehicle.

M-13,920

CREW CAPSULE EMERGENCY ESCAPE
(CARGO TRANSPORT MISSION AND FLIGHT TEST ONLY)

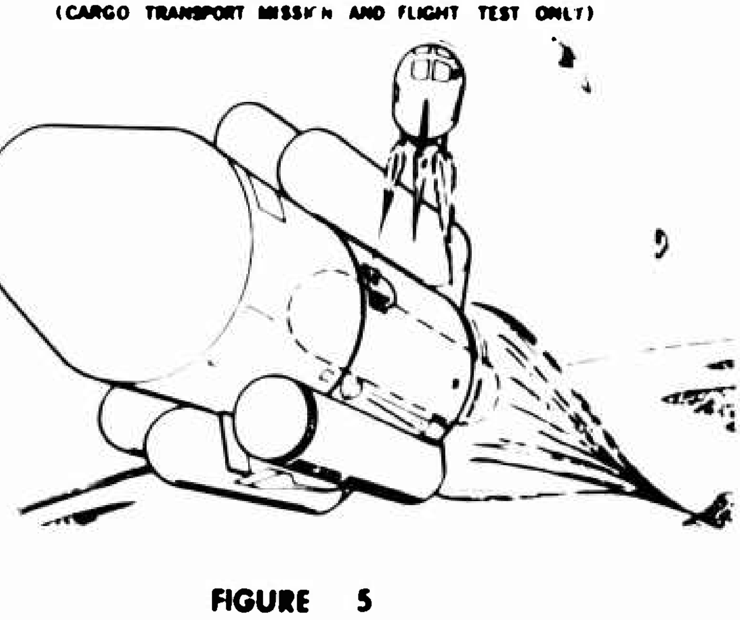

FIGURE 5

Figure 6 depicts how the recovery parachutes are deployed from their stowage compartment at the appropriate altitude. In addition, two expandable-structure pneumatic bags are deployed from beneath the stabilizing fins in order to provide stability after touch-down at sea, and to absorb impact energy during a land-recovery mode.

M-13,979

EMERGENCY CREW ABORT
(FLIGHT TEST AND CARGO TRANSPORT MISSION ONLY)

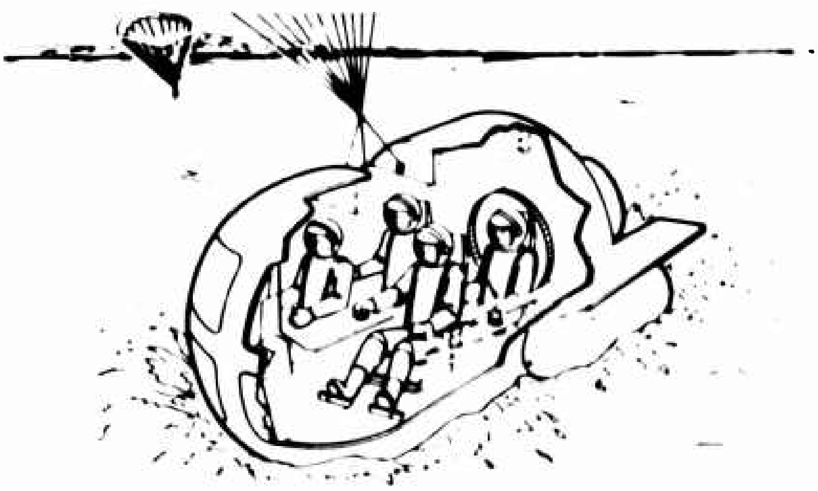

FIGURE 6

The floor plan of Figure 7 illustrates how the 200 individual troop couches are arranged on each of the six decks. During the few minutes of weightless flight, the personnel are constrained by belts attached to the couches. On a rocket-propelled ballistic mission, of the ITHACUS type, the acceleration vector during ascent and the deceleration vector during entry are oriented in the same direction with respect to the personnel; that is, the acceleration loads would be distributed by the couch to the same portion of each passenger's back during either phase of the flight regime. By comparison, where the pilot and crew are facing forward for visibility prior to landing during a glide-type re-entry, they are subjected to severe discomfort and handicap from the deceleration vector orientation (eyeballs protruded).

The floor plan illustrates proposed stowage rack locations, for the individual troop equipment, which may be required for limited warfare operations. Also shown are the access stairwells which interconnect the six decks for emergency egress. Three entry doors are located at each of the six levels for rapid loading and deployment of troops. In order to diminish the noise effect on personnel, the 70-foot diameter payload compartment would be constructed of a double-wall, acoustic-damping material.

M-13,978

ITHACUS
1200 TROOP COMPARTMENT ARRANGEMENT

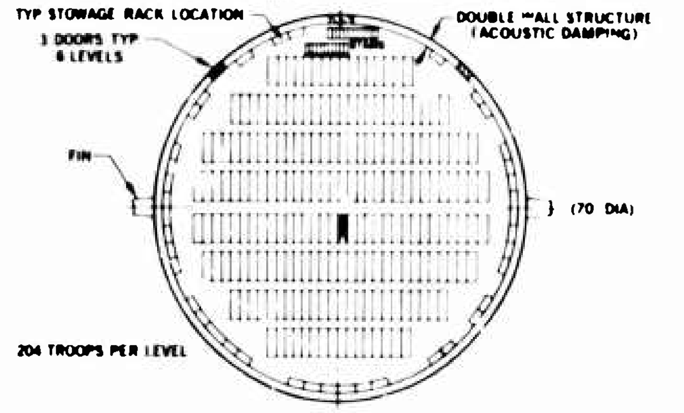

FIGURE 7

Figure 8 delineates some proposed techniques which may prove effective toward reducing the anticipated noise levels to within tolerable limits. It is estimated that the ITHACUS type of propulsion system, delivering 18-million pounds of thrust, may produce a noise level of approximately 181 decibels (db) in the vicinity of the engine. A rigorous investigation has not yet been conducted to assess the intensity of acoustic energy imposed on the payload portion of the vehicle. Nevertheless, it currently appears that some supplementary techniques must be employed to further attenuate the acoustic excitation within the troop compartment. One or more of the tabulated techniques may effectively accomplish this purpose. The noise consideration appears to present one of the major problem areas which must be resolved before personnel can be transported by rocket-powered vehicles.

M-13,953

ITHACUS NOISE REDUCTION TECHNIQUES

- REDUCTION OF NOISE AT SOURCE
  - AIR AUGMENTATION OF JET STREAM
  - OPTIMIZE LAUNCH PAD DESIGN (REFLECTED ACOUSTIC ENERGY)
  - DUCTING (DEFLECTION) OF JET STREAM
  - IMPINGEMENT OF JET ON WATER SURFACE
- REDUCTION OF NOISE IN TROOP COMPARTMENT
  - MECHANICAL ISOLATION OF FLOOR SUPPORTS AND SEATS
  - LOW MOLECULAR WEIGHT GASES (OR VACUUM) BETWEEN MULTIPLE WALLS
  - INCREASED MASS OF INNER WALL
  - INCORPORATE PANELS OF ABSORPTIVE MATERIALS
  - REDUCTION OF INTERNAL (CABIN) PRESSURE
  - REDUCTION OF MOLECULAR WEIGHT OF BREATHING GASES (HELIUM)
- REDUCTION OF NOISE ON PERSONNEL
  - ISOLATION OF EARS (EAR PLUGS, EAR MUFFS IN HELMET)
  - ISOLATION OF BODY (SEALED INDIVIDUAL ENCLOSURES HARD SPACE SUIT)

FIGURE 8

Figure 9 tabulates the breakdown of the ITHACUS payload. The term "booster payload" (500,000 pounds) is required for the POMBUS comparison and is equivalent to 264,000 pounds of usable payload, which can be comprised of either troops or cargo.

Approximately 220 pounds per man were allocated for each of the 1,200 troops with personal equipment. An appreciable allotment of 20,000 pounds was included for the weight of gas to pressurize the huge volume of the troop compartment. As previously noted, 10,000 pounds were deducted from the payload to provide for the weight of the four-man crew capsule, escape system, and environmental control system. Many of the preliminary weight estimates, shown for structural components, can be significantly reduced through more rigorous design analysis

56 percent full. The engines are throttled at lift-off to maintain a constant thrust-to-weight ratio of 1.25 A vehicle, which is designed with disposable tanks, is readily adapted to an off-loaded mission, merely by the elimination of some of the external propellant tanks. The internal oxygen tank would not be filled to maximum capacity. On some of the shorter-range missions to inaccessible destinations, propellant could be retained in the external tanks (attached to the upper side of the vehicle during entry) for "flying" the vehicle to a spaceport after land'ng and debarkation of troops.

ITHACUS PAYLOAD
PRELIMINARY WEIGHT ESTIMATE

TROOPS (1200 MEN AT 180 LB/MAN)	USEFUL PAYLOAD	216,000 (LB)
TROOP EQUIPMENT (40 LB/MAN)	USEFUL PAYLOAD	48,000
TROOP PROVISIONS (20 LB/MAN – SEATS, RESTRAINT)		24,000
CABIN PRESSURIZATION SYSTEM AND GAS (7.5 PSIA)		20,000
CABIN STRUCTURE (CYLINDRICAL SIDEWALL, PRESS BULKHEADS, AND FLOORING)		145,000
ACOUSTIC DAMPING PROVISIONS **		12,000
NOSE FAIRING **		25,000
CREW SYSTEM (4 CREWMEN, CAPSULE, ESCAPE SYS., ENVIRONMENTAL SYS. ETC) *		10,000
BOOSTER PAYLOAD TO 7600 N MI RANGE (USEFUL PAYLOAD TO 7600 N MI RANGE = 264000 LB)		500,000 (LB)

* FOR FLIGHT TEST & CARGO TRANSPORT MISSION ONLY
** SUBJECT TO FURTHER DESIGN REFINEMENTS

FIGURE 9

ITHACUS ACTUAL PAYLOAD VS RANGE FOR 3 g-LIMITED MISSION

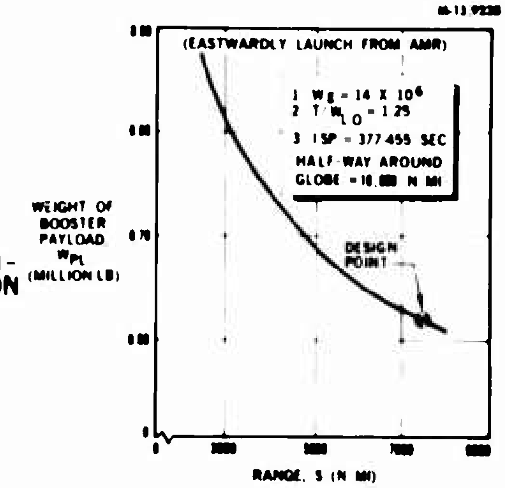

FIGURE 10

Mission Profile

Since a ballistic transport vehicle, of the type described, must have launch capability in any direction (easterly or westerly), a non-rotating earth was assumed for the preliminary estimate of payload capability. Figure 10 illustrates the increase in payload which can be acquired during an easterly launch. For example, the nominal 500,000-pound booster payload (to a 7,600 nautical mile range) can be increased to 620,000 pounds, due to the added velocity imparted to the vehicle from the earth's rotation, during an easterly launch. The propulsion system specific impulse varies from 377 seconds (at sea level) to 455 seconds (at vacuum conditions). These values are based on assumed chamber pressure of 3,000 psi, with a 7 to 1 mixture ratio (of oxygen to hydrogen) and an expansion ratio of 200 to 1, which is provided by the altitude compensating nozzle.

With the assumption of two launch-pad locations (one at AMR, the other at PMR), a range half-way around the world (10,800 nautical miles) is not required in order to reach the key destinations which were assumed. Clearly, such a range also can be realized by trading payload for added propellants. Figure 11 tabulates the distance and transit times for the ITHACUS vehicle to 14 representative cities of the world. For the maximum-range missions (such as AMR to Bombay or PMR to Singapore), the vehicle would be fully loaded with propellants. When the payload is maintained at constant weight, the propellant would be off-loaded, prior to lift-off, in order to perform the shorter-range missions. For example, a mission from AMR to London would necessitate propellant tanks only

Figure 11 tabulates the transit times of the ITHACUS vehicle to 14 principal cities, as compared with that required for today's jet transport and, also, with that required by the proposed supersonic transport, which was assumed to travel at 2.5 times the speed of sound. It should be noted that neither the supersonic transport, nor the jet transport, will possess the extensive range capability of an ITHACUS-type vehicle. Assuming that the supersonic transport could travel the 7,500 nautical miles from PMR to Singapore without stopping to refuel, its flight would consume seven times the duration required by the ITHACUS vehicle. The jet transport would necessitate a travel-time approximately 20 times greater.

M-13,9340

BALLISTIC TRANSPORT CAPABILITY ESTIMATE TO PRINCIPAL CITIES OF THE WORLD

DESTINATION	LAUNCH SITE	GLOBAL DISTANCE (N. MI.)	VEHICLE PROPELLANT LOADING (% FULL)	EST TRANSIT TIME: GLOBAL TRANSPORT (ROCKET) (MIN.)	EST TRANSIT TIME: SUPERSONIC TRANSPORT (MACH 2.5) (HR.)	EST TRANSIT TIME: JET TRANSPORT V = 580 MPH (HR.)
1. DAKAR, SENEGAL	AMR	3080	54	25	2.1	6.5
2. LONDON, ENGLAND	AMR	3790	56	26	2.2	6.8
3. RIO DE JANEIRO, BR	AMR	3810	57	26	2.2	6.9
4. BUENOS AIRES, ARG	AMR	3970	58	26	2.3	7.2
5. MOSCOW, USSR	AMR	4880	64	30	2.9	8.8
6. CAIRO, EGYPT	AMR	5880	68	33	3.3	10.1
7. CAPETOWN, SO. AF	AMR	6610	76	36	3.8	11.8
8. BOMBAY, INDIA	AMR	7100	98	39	4.4	13.5
9. FAIRBANKS, ALA	PMR	2030	80	17	1.2	3.7
10. HONOLULU, HAWAII	PMR	2140	82	18	1.3	3.9
11. TOKYO, JAPAN	PMR	4640	77	30	2.7	8.4
12. NOVOSIBIRSK, USSR	PMR	5270	87	32	3.1	9.5
13. MELBOURNE, AUS	PMR	6810	96	37	4.0	12.3
14. SINGAPORE, MAL	PMR	7510	100	39	4.4	13.5

ITHACUS P/L = 0.8 M. LB. (USEFUL P/L = 264K. LB.) MAX. RANGE = 7600 N. MI.

FIGURE 11

The 14 locations tabulated in the previous figure, and their relative location from the two assumed launch sites, are shown on the map of Figure 12. These 14 cities were not completely arbitrary in their selection. They were selected since they are normally accepted by commercial air carriers as principal locations for establishing global network coverage.

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GLOBAL TRANSPORT

ESTIMATED DISTANCE & TRAVEL TIMES FROM AMR & PMR TO 14 KEY CITIES FOR WORLD-WIDE COVERAGE

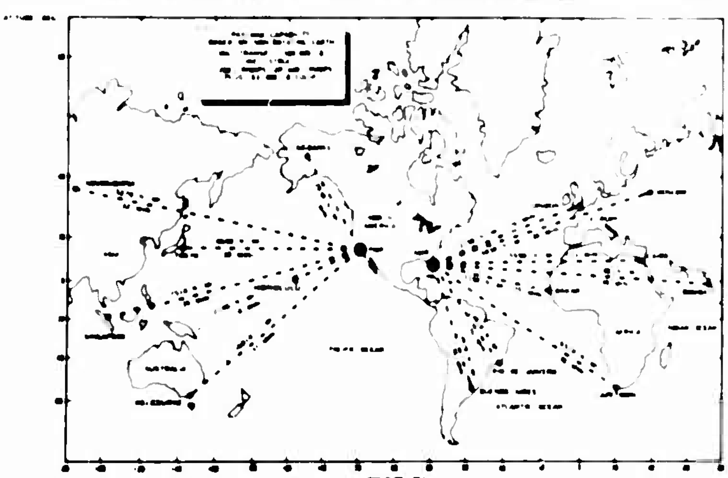


FIGURE 12

Figure 13 illustrates a typical mission profile which would result from an imposed 3-g limitation during boost and entry. Booster burn-out would occur approximately 6 minutes after lift-off at an altitude of 82 nautical miles and a velocity of approximately 24,300 fps. The vehicle would coast for an additional 7.5 minutes until apogee was acquired. At this point, the velocity has decreased to 24,150 fps. The apogee altitude of 127 nautical miles is well above the edge of the sensible atmosphere. Most of the mission would be accomplished above the atmosphere where drag is non-existent. Some 10 minutes after apogee condition, the vehicle will start the entry portion of the flight profile when it again approaches the edge of the atmosphere at an altitude of approximately 400,000 feet. The reaction control system will orient the vehicle into the required 49 degrees nose-up attitude prior to entry.

At lift-off, due to the engine thrust-to-weight ratio, the vehicle is accelerated at 1.25 g's. As propellant is depleted, and the acceleration increases, the engines are throttled in order to restrict the maximum to 3 g's. This condition is maintained until main engine cut-off. During re-entry, the vehicle again is restricted to a 3-g maximum condition. The bank angle is modulated, at constant altitude, to satisfy this condition. A 52-degree angle-of-attack will produce a vehicle lift-to-drag ratio of approximately 0.42. After the horizontal velocity has completely decayed, and the vehicle has reached a stalling condition, the attitude control system will orient the vehicle through an angle of 77 degrees until the base is pointed directly downward. A few segments of the propulsion system are then restarted in order to cancel the vertical velocity. The vehicle has the capability of hovering and translating horizontally prior to settling down on the four extensible legs.

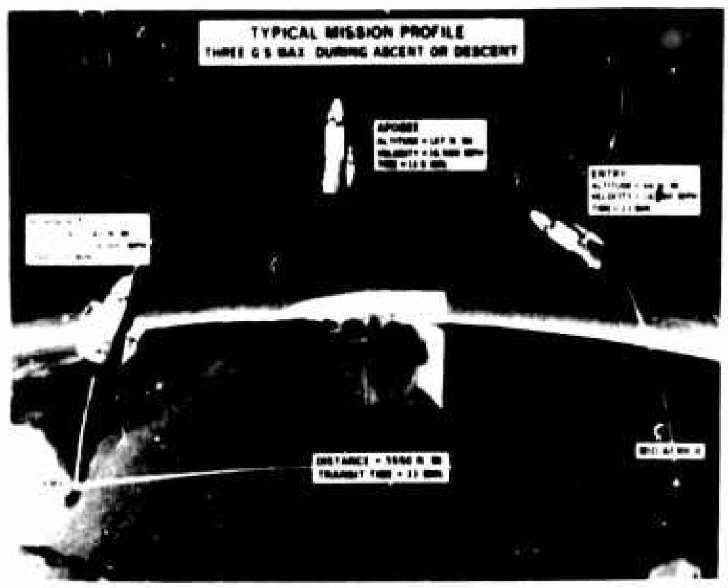


FIGURE 13

Figures 14 through 24 depict the various phases of the mission profile from troop loading to debarkation. Prior to loading of troops, the vehicle would be completely checked out and propellant tanks would be filled. Constant topping would assure that the propellant in the tanks was at the proper level prior to lift-off.

The troops would enter the vehicle through a gantry tower, incorporating a number of elevator platforms which lead to the loading ramps. Three ramps service the entry doors at each of the six deck levels of the vehicle payload. Three entry doors, placed between the external LH_2 tanks, will expedite the loading and unloading operations. During re-entry, these door openings are located on the upper side of the vehicle, keeping the highly heated underside free of structural openings and discontinuities.

FIGURE 14

In many instances, where instant-strike capability is required, squadrons of B-52 aircraft are kept airborne around the clock. Under similar circumstances, it may prove feasible to maintain ITHACUS in a state of instant readiness, with troops loaded on-board the vehicle, prepared for immediate dispatch to a potential trouble area. The propellant required for chill-down, and for topping of the tanks during an 8-hour ground hold with troops aboard, was estimated. It was calculated that an additional 9 percent of LH_2 (based on tank capacity) and an addition 1.6 percent of LO_2 would compensate for the boil-off losses resulting from these conditions. Re-call and re-direction capability could be incorporated into the on-board computer which controls vehicle guidance to predetermined destinations. The crew would be provided with manual over-ride of the computer.

ITHACUS ASCENT

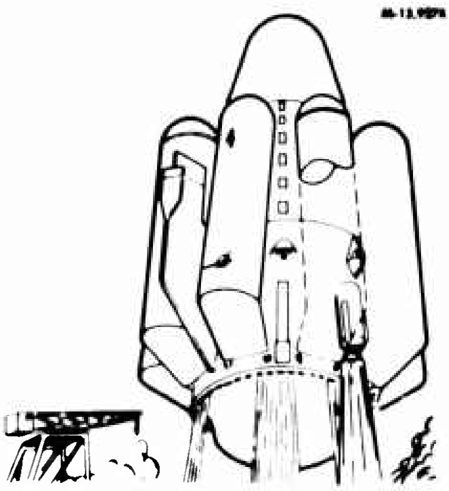


FIGURE 15

During a normal ascent, ITHACUS would rise almost vertically for about 70 seconds. In the event of an engine malfunction, or an emergency abort condition, the eight external tanks can immediately be separated and jettisoned at sea; containing the hazardous liquid hydrogen. The major portion of the liquid oxygen would be pumped overboard from the internal tank through the turbine discharge port located in the center of the engine plug nozzle. In the event of an aborted mission, ample propellant would be retained on board to assure that adequate retro-thrust can be provided, prior to sea recovery of the entire vehicle. In this sense, a rocket-powered VTOL, which can use an entire ocean as its emergency landing site, may be inherently safer than a jet aircraft which must depend on reaching a particular airport for an emergency landing if trouble develops.

ITHACUS
PROPELLANT DUMPING-LAUNCH ABORT
(LH_2 TANK JETTISON & LO_2 OVERBOARD PUMPING)

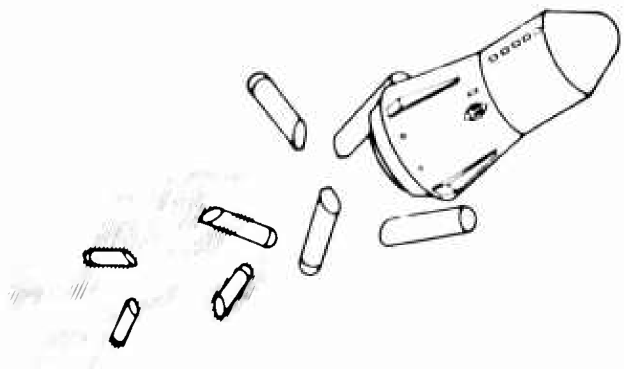


FIGURE 16

After dumping of propellants, four expandable-structure spheres would automatically be deployed from the extended landing legs to assure hydrostatic stability of the entire vehicle after alighting on the ocean. During this emergency recovery mode, the vehicle would be towed back to port. Numerous surface vessels and tow lines are used to stabilize the vehicle against adverse wind effects during retrieval.

ITHACUS LAUNCH ABORT
(ALTERNATE RECOVERY MODE)

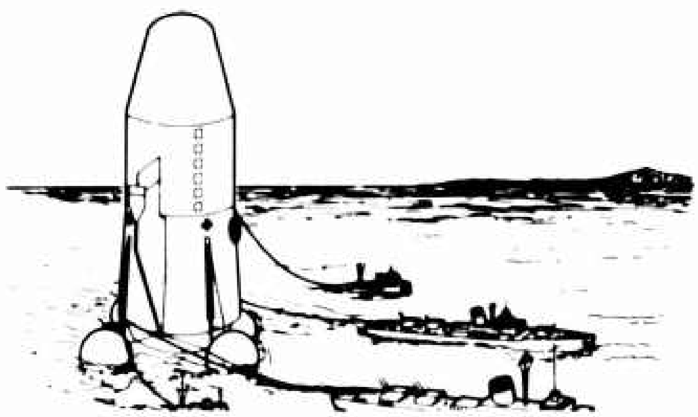


FIGURE 17

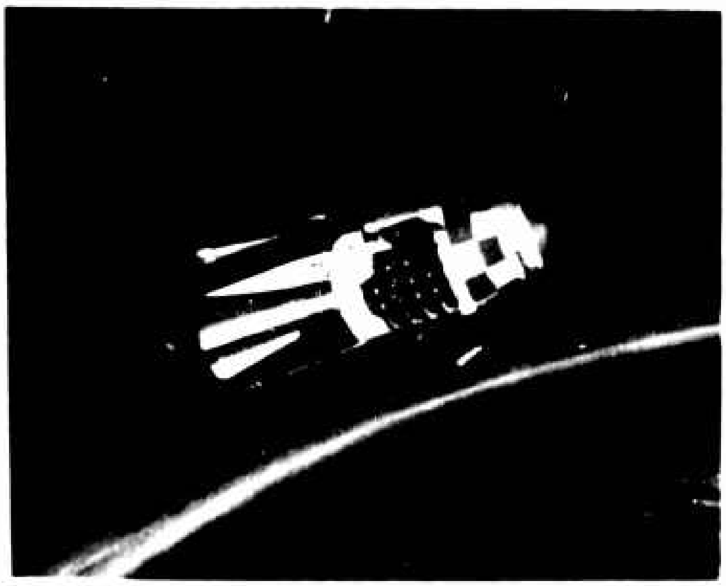


FIGURE 18

START RE-ENTRY

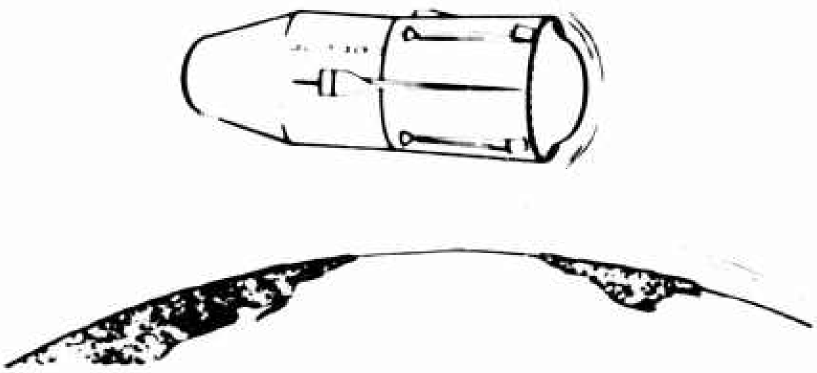


FIGURE 19

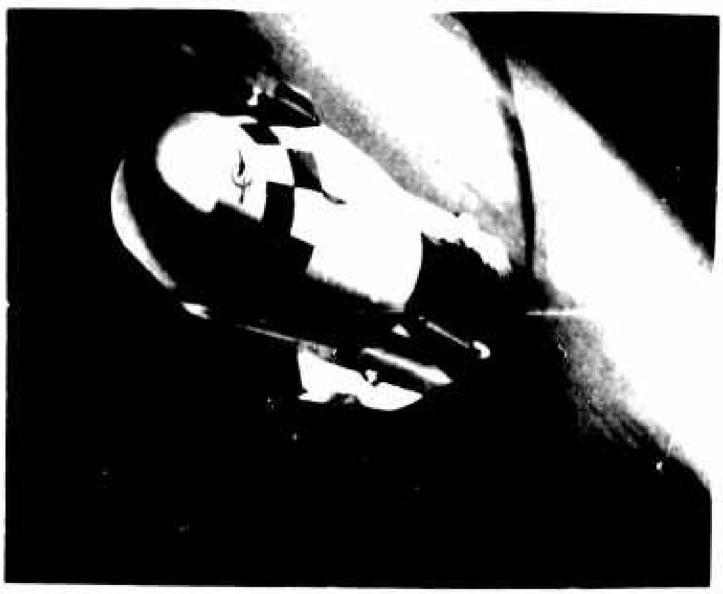


FIGURE 20

TERMINAL RETRO THRUST—2500 FT.

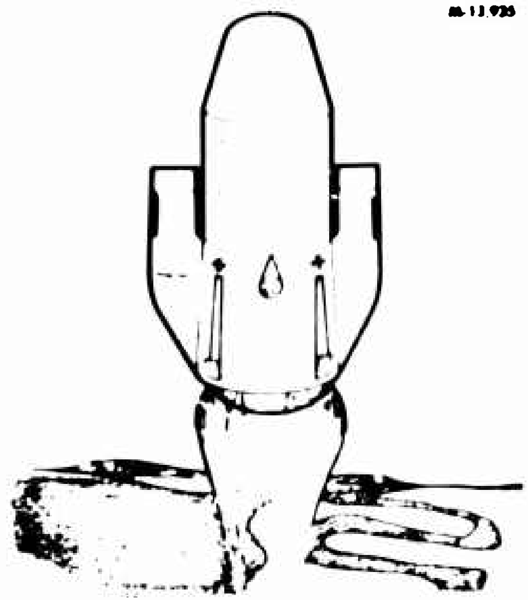


FIGURE 21

FIGURE 22

The pilot's and co-pilot's compartment incorporates unobstructed downward-vision windows to confirm the suitability of the touch-down location. Rapid deployment of troops would be a mandatory requirement for such a military operation. A number of potential techniques and devices, which would be employed to assure immediate unloading of troops and support equipment, are illustrated in Figure 23.

PILOT'S DOWNWARD VISION
(PRIOR TO TOUCHDOWN)

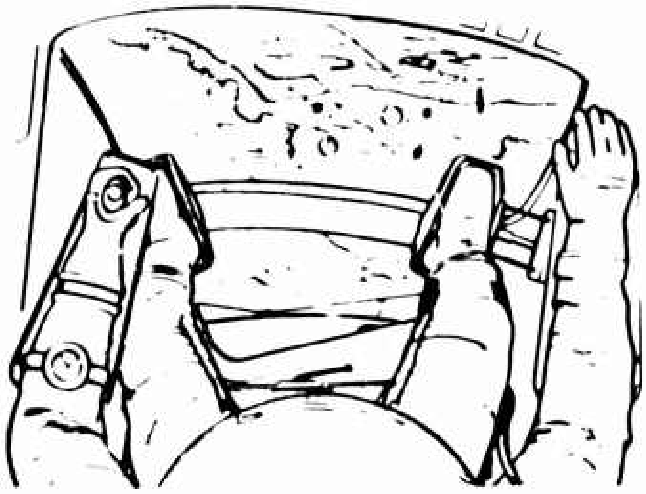


FIGURE 23

The ITHACUS propulsion system is comprised of 36 toroidal combustion chambers which each produce 500,000 pounds of thrust at lift-off. After re-entry, selective engine modules are ignited at an altitude of 2,500 feet to provide retro-thrust for terminal velocity cancellation. At re-ignition, only 2 million pounds of total thrust are required to produce almost 2 g's of deceleration. These modules are progressivly throttled for 12 seconds; they then produce 1.28 million pounds of total thrust to balance the recovered weight. Roll control is provided by the attitude control system. Since only eight modules (of the available 36 segments) are operated at half-thrust (or lower) during this maneuver, extensive redundancy and improved mission reliability are provided at no additional weight penalty. After the hover maneuver, the engines are automatically cut off when the landing legs are compressed, as shown in Figure 24.

FIGURE 24

On a typical mission to mid-Africa, it appears feasible to recover the vehicle after troops have been unloaded. Although rigorous cost analysis has not yet been conducted for ITHACUS, an extensive investigation (Reference 13) resolved the cost of the ROMBUS "parent" vehicle at approximately $164 million for the first flight item and at an average cost of $56 million per copy, for a sample of approximately 150 vehicles. It, therefore, appears that the reuse of the troop transport would be extremely attractive, even when the vehicle is located at a remote, inaccessible, land-locked destination. In such an event, limited propellants would be "trucked" in on ground vehicles which can traverse the difficult terrain (Figure 25). After refueling, the vehicle could then make a short "flight" to the nearest coastline, where a "crawler" would lift it and transport it to a waiting barge. Return of the vehicle to the refurbishment and relaunch site would be accomplished in a manner similar to the ROMBUS ground operations, as defined in Reference 1 (see Figure 26).

REFUELING ITHACUS PRIOR TO FLIGHT TO RECOVERY PORT
LIMITED PROPELLANT QUANTITIES REQUIRED

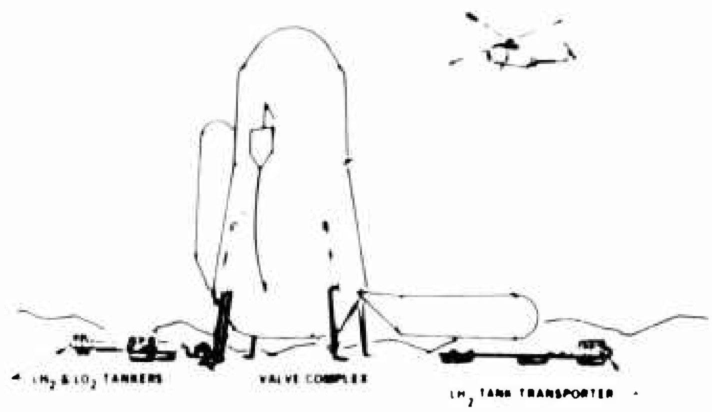


FIGURE 25

Although the suggestion of launching a booster directly from its landing legs (without a launch pad) may appear rather unrealistic, "it's not necessarily so." It should be clarified that the Apollo mission depends on precisely such an operation, on the return phase. The Lunar Excursion Module (LEM) is launched, while supported by its four legs, from the lunar surface, where no Cape Kennedy is known to exist.

In time, perhaps, the launch complex, which was required at the outset of the mission, may be dispensed with, although it appears that initial operations would be conducted from a launch pad. During the retrieval flight of ITHACUS, the required engine thrust is at a greatly reduced level, since the vehicle is essentially empty. Therefore, the problems attendant with the engine noise level, and with the exhaust plume effects on the touch-down surface, are significantly diminished.

ITHACUS RECOVERY AFTER FLIGHT FROM INTERIOR

(VEHICLE DELIVERED TO THEATER OPERATIONS CENTER

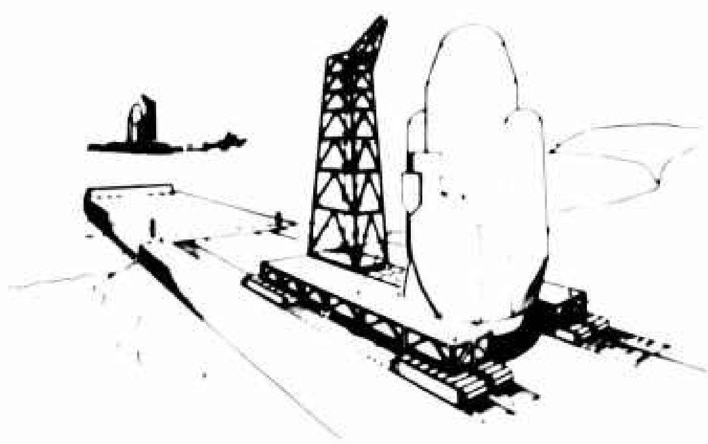


FIGURE 26

Parametric Mission Criteria

Figure 27 presents an historical plot of the ascent trajectory for a representative mission from AMR to mid-Africa. The parameters of velocity, altitude, flight-path angle, and acceleration are plotted as a function of time from lift-off. The initial thrust-to-weight ratio of 1.25 will build up to approximately 3 g's after 150 seconds of flight. Acceleration is maintained at 3 g's, for 3.5 minutes until burn-out, by progressive throttling of the main engines as propellant is consumed. The plot defines the point at which the first four external hydrogen tanks are jettisoned, some 135 seconds after lift-off. The propellant is depleted from these four tanks concurrently. In order not to adversely affect the vehicle's stability, the tanks are separated simultanesouly. Approximately 240 seconds after lift-off, the next pair of tanks are jettisoned, with the last pair ejected just after main engine cutoff, 350 seconds after lift-off. These tanks are parachute-recovered, from the ocean, by an LDS, as described in Reference 1.

ITHACUS EXIT TRAJECTORY

AMR TO AFRICA (RANGE = 5600 N MI)

NOTES 1 $W_g = 14 \times 10^6$ LB 2 $T/W_{LO} = 1.25$ 3 I_{sp} = 377/455 SEC

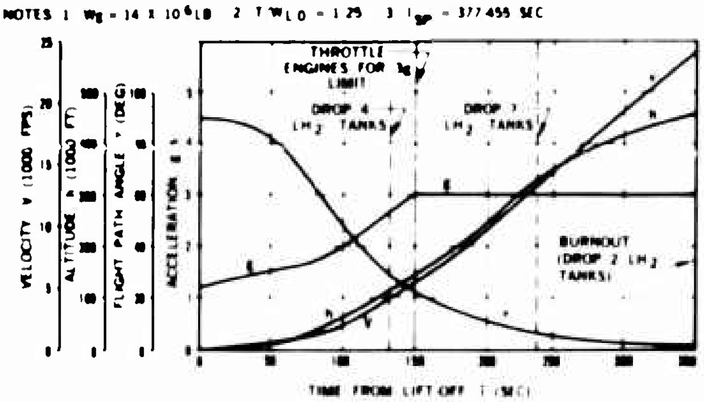


FIGURE 27

The control surfaces of the two fins (located between the hydrogen tanks) are stowed in the locked position during ascent. As the vehicle is boosted through the atmosphere, the trailing edge of these control surfaces will be subjected to heat flux. Figure 28 is an historical temperature plot of the control surface edge. Six minutes after lift-off, this edge reaches a maximum temperature of approximately 1,100 degrees Fahrenheit. On the outboard edge of the fin, in the vicinity of the vertical control surface, the structure will be subjected to a maximum temperature of only 200 degrees Fahrenheit. The trailing edge was assumed to be constructed of stainless steel, formed into a 3-foot radius. One potential problem area, which has not been subjected to rigorous investigation, is the degree of shock wave reflection between the LH_2 tanks and the fin surfaces. The intensity of heating and buffeting, which may result from these interactions, should be initially resolved through wind-tunnel testing.

ITHACUS FIN BOOST TEMPERATURE HISTORIES

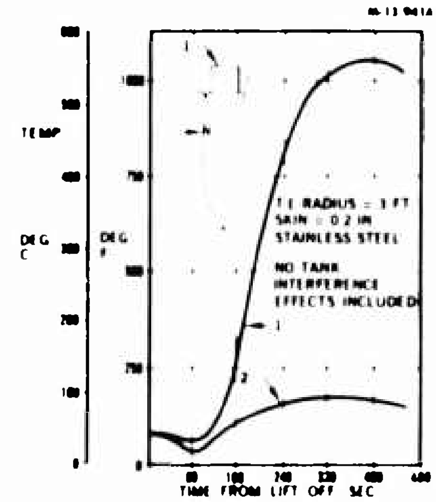


FIGURE 28

Figure 29 plots the atmospheric entry phase of the mission trajectory. By resorting to lift modulation by varying the bank angle during entry, the deceleration can be restricted to a maximum value of 3 g's. After the initial peak deceleration, the physiological loads vary between 1.0 and 1.5 g's for the remainder of the trajectory. It should be noted, however, that the troops would be subjected to more than 2 g's for only a period of approximately 1.5 minutes. The personnel would then have available an 8-minute interval for recovery from 2 g's prior to active debarkation. The peak deceleration load occurs 190 seconds after entry. Shortly, thereafter, the vehicle is banked through an angle of 70 degrees (around the velocity vector), which is progressively decreased during an interval of 200 seconds. During this interval, the vehicle maintains a constant altitude of 160,000 feet and a constant flight-path angle of zero degrees. The initial flight-path angle of 2.7 degrees, down from the local horizontal at entry into the edge of the atmosphere (400,000 feet), is decreased to zero degrees within 3 minutes. The vehicle is maintained at a constant angle-of-attack of 52 degrees from the velocity vector throughout the entire regime of the entry maneuver. Approximately 12.5 minutes after entry, when the propulsive portion of the landing maneuver

is initiated, the vehicle has traversed some 1,650 nautical miles of range from the point of atmospheric insertion, and the flight path angle has increased to 65 degrees below the horizontal. The vehicle centerline is oriented 49 degrees above the horizontal, at start of entry, and 13 degrees down from the horizontal at the end of the atmospheric entry.

ITHACUS PRELIMINARY ENTRY TRAJECTORY

M-13,942A

BANK ANGLE – MODULATED ENTRY

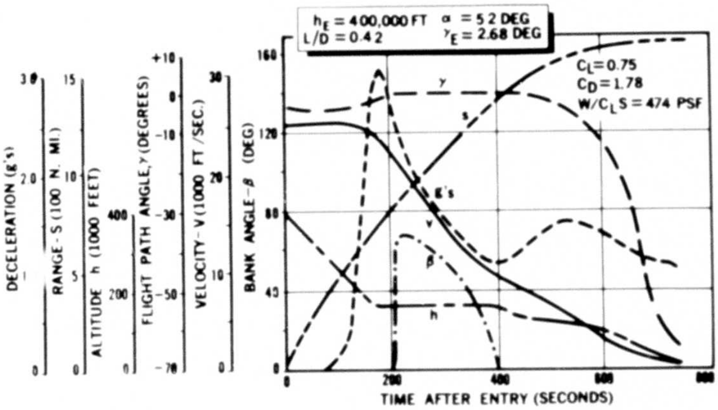


FIGURE 29

Figure 30 compares maximum re-entry temperature of the ITHACUS vehicle with comparable values for the ill-fated X-20 Dynasoar. The 4,000 degree Fahrenheit nose temperature of the X-20 is analogous to an equivalent 600 degree Fahrenheit nose temperature of ITHACUS, due to the effective cooling of the ITHACUS nose by circulation of liquid hydrogen. The blunt nose of the ITHACUS configuration provides an added fringe benefit. The shock wave propogated from the nose of this blunt entry body will protect the fin leading edges from severe heating conditions. The fin leading edge of the X-20 glider is shown to be approximately 3,000 degrees; the ITHACUS vehicle, approximately 2,500 degrees. It should be noted, however, that these values are theoretical maximum temperatures which do not allow for any heat-sink capability for the vehicle structure. The following figures present the actual maximums predicted for the pertinent hot-spots on the vehicle structure. The ITHACUS fins were sized to allow approximately 4,000 square feet of total surface area. The entire area can be contained within the envelope defined by the external hydrogen tanks. Hence, wind shear gradients during boost are not imposed directly on the fin surface area; otherwise resulting in severe de-stabilizing moments.

M-13,943A

MAXIMUM RADIATION EQUILIBRIUM TEMPERATURES FOR WINGED VEHICLES DURING ENTRY

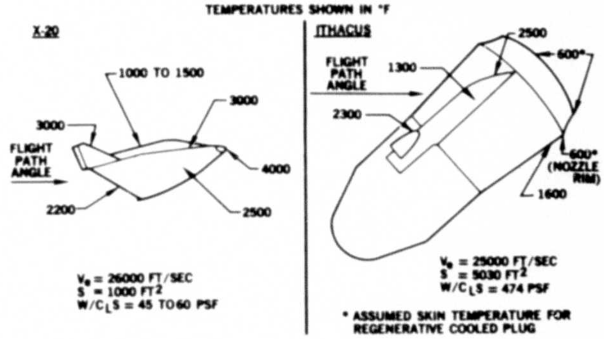


FIGURE 30

Figure 31 is an historical plot of the main body entry temperature for ITHACUS. It indicates that a maximum of approximately 1,350 degrees Fahrenheit is reached some 480 seconds after atmospheric penetration. This temperature is associated with a stainless steel (3-inch honeycomb sandwich) construction for the underside of the body, with external skins approximately .080 inches thick. When thickness, and resulting heat stowage capability, is attributed to the material of the vehicle, it is evident that the theoretical maximum of 1,600 degrees Fahrenheit (shown in Figure 30) will be reduced to approximately 1,350 degrees Fahrenheit. The 5,030 square foot reference area, indicated in Figure 31, is the cross-sectional area of the 80-foot diameter base.

M-13,945A

ITHACUS MAIN BODY RE-ENTRY TEMPERATURE HISTORY (T_{MAX})

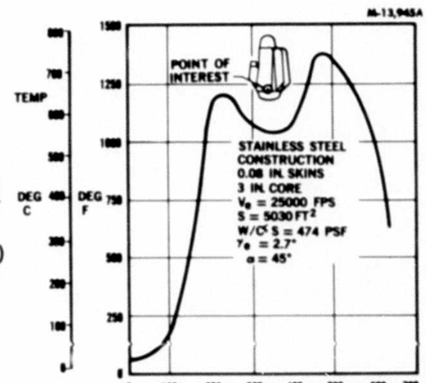


FIGURE 31

Figure 32 is a plot of the fin leading-edge temperature and indicates that a maximum of 2,000 degrees Fahrenheit is reached approximately 220 seconds after atmospheric entry, as compared to the 2,500 degree Fahrenheit theoretical maximum shown in Figure 30, or the 3,000 degree Fahrenheit leading edge temperature of the X-20. The plot of Figure 32 is based on an assumed leading-edge radius of 2-1/2 feet and stainless steel construction with a skin thickness of .2 inches.

ITHACUS FIN LEADING EDGE TEMPERATURE HISTORY

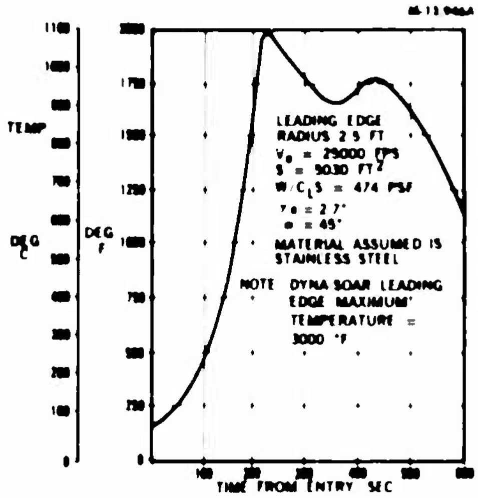


FIGURE 32

The plot of Figure 33 defines the variation of the previous maximum temperature (2,000 degrees Fahrenheit), as a function of the stainless steel sheet thickness. When the thickness is halved, the maximum temperature will increase to approximately 2,400 degrees Fahrenheit. When the leading-edge thickness is doubled, the maximum temperature would be decreased to approximately 1,400 degrees Fahrenheit.

ITHACUS FIN LEADING EDGE MAXIMUM TEMPERATURE VARIATION WITH SKIN THICKNESS

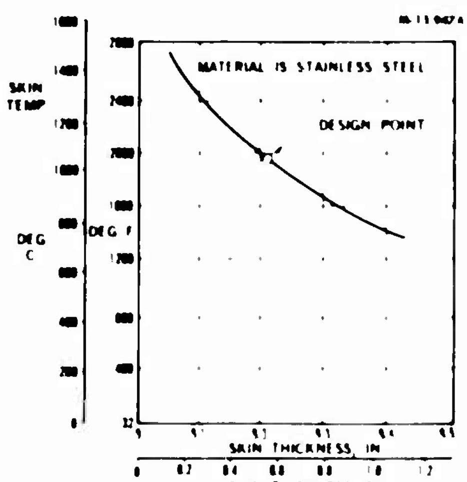


FIGURE 33

Although a high L/D lifting body would provide greater maneuverability during the entry phase, a moderately low lifting body appears to provide suitable control capability. Figure 34 plots the variation of the ITHACUS L/D ratio ($C_L = 0.75$, $C_D = 1.78$) as a function of the angle-of-attack. It can be seen that a maximum L/D of about .42 can be acquired at angle-of-attack values between 45 degrees and 55 degrees. At a zero angle-of-attack, no lift is generated by the ITHACUS vehicle; resulting in a pure ballistic re-entry with its exceedingly high decelerations, as previously discussed.

ITHACUS EFFECT OF ANGLE OF ATTACK ON LIFT TO DRAG RATIO

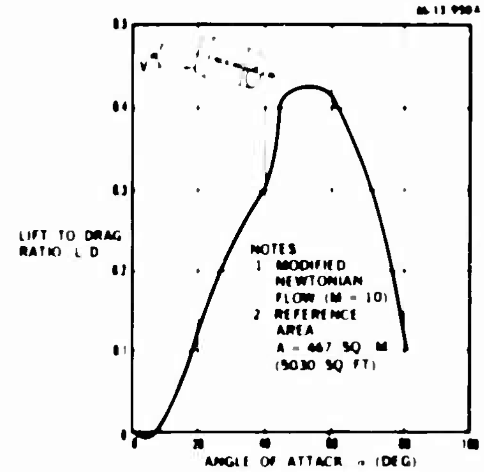


FIGURE 34

Figure 35 is a plot of the maneuverability which is predicted for a vehicle of the ITHACUS type. When a constant bank angle is maintained throughout the initial 3 minutes and final 6 minutes of entry (excluding the constant-altitude portion), the down-range and cross-range maneuver capability can be varied as shown. The nominal design point of the ITHACUS vehicle, which allows a maximum deceleration of 3 g's during re-entry, would be acquired with a constant bank angle of 50 degrees. Under these conditions, the down-range maneuver capability could be varied by 1,500 nautical miles, with the cross-range touch-down point controlled to approximately 120 nautical miles. These variations are defined as dispersions from the nominal touch-down location resulting from pure ballistic entry (without lift capability). During a ROMBUS ballistic recovery from orbit (at an angle of 1.5 degrees), it was estimated that the 3-sigma touch-down dispersions would be contained within an ellipse having a 13.6 nautical mile major axis and a 1.6 nautical mile minor axis (C.E.P. = 1.53 nautical miles).

After ITHACUS horizontal velocity cancellation, selective segments of the propulsion system would be re-ignited to provide hover and horizontal translation capability for the vehicle. It is estimated that approximately 60,000 pounds of on-board propellant would be required to allow the vehicle to hover, then pitch over 10 degrees, and translate 1,000 feet horizontally in 30 seconds.

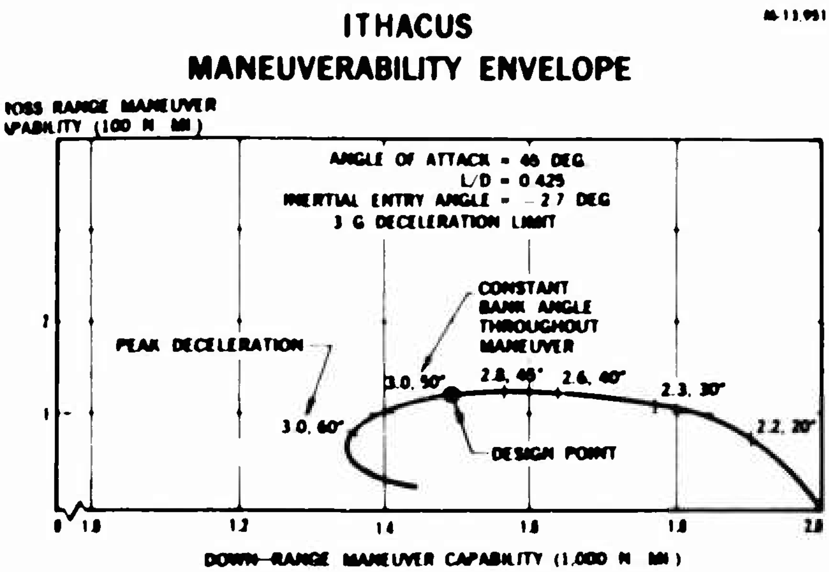


FIGURE 35

One major consideration, which must be reckoned with when considering a troop transport mission of the ITHACUS type, would involve the time required to prepare the vehicle for flight readiness. The time-consuming preparations and count-down procedures, required for today's expendable boosters, would render a rocket-transport mission impractical. Since ITHACUS would not be operational until the early 1980's, it is not unrealistic to postulate that, after booster reuse has become commonplace, the flight readiness time may be diminished to a level comparable to that of today's commercial aircraft; that is, from touch-down to the next consecutive flight.

For the HOMBUS reusable orbital booster, it was estimated that 76 days would be initially required for vehicle turn-around time from first launch to first re-launch. This conclusion was based on the following time estimates: 1) vehicle refurbishment required 16 days, 2) one week stay-time of vehicle on launch pad, and 3) one week required for launch pad refurbishment. It is an impossible task to postulate, conclusively, the degree of increased confidence level and reduced launch preparations which will result from repeate booster reuse. Only experience can be substituted for speculation and conjecture on these vital considerations. Clearly, it is imperative that time-consuming pre-flight operations must be minimized. Toward this end, the ITHACUS vehicle would contain on-board automatic check-out equipment to provide instant readiness.

The premise of reduced turn-around time accepted, the major consideration remaining, to influence the feasibility of rocket-borne troop transports, would be that time required for loading and unloading of the vehicle. Figure 36 tabulates estimated loading times, comparing the ITHACUS military transport with equivalent numbers of military aircraft, which would be required to accomplish the same payload-carrying mission. The rocket transport would require approximately twice as long to load 600 troops and 132,000 pounds of cargo, as the ten equivalent aircraft would necessitate. During the unloading operation, it is estimated that the troops from the rocket transport could be debarked in slightly more time than is required for comparable aircraft. However, cargo unloading from the rocket transport would require approximately twice as long, as the aircraft, due to the 100-foot (or more) height from ground level of the cargo carried aboard.

M 14290A

GLOBAL TRANSPORT VS PLANE
LOADING AND UNLOADING TIME COMPARISON

EVENT (TIME IN MIN)	600 TROOPS + 132,000 LB CARGO** ITHACUS MILIT (1) VEHICLE		AIRCRAFT MILIT (4) DC-8F PLUS (6) C 141*	
LOADING TIME	TROOPS	CARGO	TROOPS	CARGO
FROM TERMINAL TO LOADING RAMP	18	25	15	15
LOADING RAMP TO VEHICLE	48	62	15	25
FINAL READINESS	5	9	4	5
TOTAL	71	96	34	45
UNLOADING TIME				
FROM TOUCH DOWN TO UNLOADING	30	80	19	30
UNLOAD RAMP TO TERMINAL	7	5	15	15
BAGGAGE RE CLAIM	—	—	—	—
TOTAL	40	85	34	45

*TIMES ASSUME SIMULTANEOUS LOADING OF ALL AIRCRAFT
**CARGO IS CARRIED IN 5,000 LB LOADS ON PALLETS

FIGURE 36

Figure 37 compares the ITHACUS vehicle, with its landed weight of 1.28 million pounds, with three typical military aircraft which vary from 270,000 pounds to 80,000 pounds at touch-down. The table indicates that the ITHACUS vehicle, even when only three of its four legs are loaded on touch-down, can land on any type of terrain, with the exception of quick-sand or silt. By comparison, the B-52C and DC-8 could not be supported by anything other than hard rock, which has an allowable bearing pressure of 50 tons per square foot. The C-118, however, could be supported by soft rock, which has an allowable bearing pressure of 8 tons per square foot. For a typical mission (from AMR to mid-Africa), the table shows that the weight of the ITHACUS troop transport could readily be supported on coarse sand (such as is found in the Sahara desert) by moderately-sized landing pads (6-feet square) on each of the four landing legs.

M 142990

GLOBAL TRANSPORT VS AIRPLANE
LANDING LOAD COMPARISON

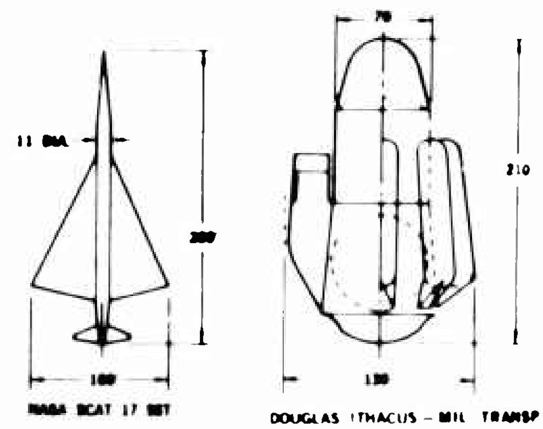
SOIL TYPE	ALLOWABLE BEARING PRESSURES TONS/SQ FT	ITHACUS MIL TRANSP 4-LANDING LEG CONFIG (3 LEGS LOADED) LANDING WT 1.28 M LB FOOT PRINT DIMENSIONS (LOAD/LEG)	AIRCRAFT COMPARISON* (AVG BEARING LOAD TIRE PRESSURE + 10%) B-52C (270K LB)	DC-8 (280K LB)	C-119 (80K LB)
QUICKSAND SILT	0.5	LOADS WILL EXCEED SOIL BEARING STRENGTH	LOADS WILL EXCEED SOIL BEARING STRENGTH		
DRY CLAY OR FINE SAND	2.5	8 x 11 (2.4 T/FT²)			
HARD CLAY & SAND (MIXED)	5.0	7 x 7 (4.4 T/FT²)			
GRAVEL & FIRM COARSE SAND (MIXED)	6.0	6 x 6 (6.0 T/FT²)			
SOFT ROCK	8.0	5 x 6 (7.1 T/FT²)			8.4 T/FT²
HARD ROCK	50.0	4 x 4 (13.4 T/FT²)	18 T/FT²	14.4 T/FT²	

*DISREGARDS LENGTH OF PREPARED LANDING STRIP REQUIRED

FIGURE 37

Figure 38 compares ITHACUS with one proposed version of the SST (supersonic transport). Although ITHACUS has approximately eight times the payload capability of the SST, its gross weight is 28 times larger, and its landing weight is 4.5 times greater. It has a range two and one-half times as great as the SST. Its cruising speed, as indicated in Figure 38, would be eight and one-half times that of the SST. The principal advantages offered by the ballistic transport are: 1) transit time reduction and 2) elimination of the requirement for a landing runway. Undoubtedly, one parameter influencing the evolution of an ITHACUS-type vehicle will be its cost-effectiveness. As indicated by the figure, it does not appear that a rocket-powered vehicle, using high-energy propellants, can effectively compete with airplanes on an operational cost basis.

TRANSPORT VEHICLE COMPARISON



	NASA SCAT 17 SST	DOUGLAS ITHACUS - MIL TRANSP
TOTAL USEFUL PAYLOAD WEIGHT	[illegible] LB	[illegible] LB
PASSENGERS	26,300 LBS (125 PASS. + BAGGAGE)	132,000 LBS ([illegible] TROOPS + EQUIP)
CARGO	[illegible] LB	[illegible] LB
GROSS WEIGHT	[illegible] LB	[illegible] LB
LANDING WEIGHT	[illegible] LB	[illegible] LB
THRUST	[illegible] LB	[illegible] LB
RANGE	[illegible]	[illegible]
CRUISING SPEED	[illegible] MPH	17,[illegible] MPH
TRANSIT TIME FOR 7000 N.M. DISTANCE	4.4 HRS (THEO.)	[illegible] MIN
RUNWAY LENGTH - TAKEOFF	[illegible] FT	0
- LANDING	[illegible] FT	0
SEAT MILE COSTS (D.O.C.)	1 1/2-2 CENTS/N.M.	7 CENTS/N.M. (FUEL ONLY) (REUSABLE VEHICLE)

FIGURE 38

When a large number of reuses can be realized for each vehicle, the operational costs are comprised, principally, of launch costs and the cost for propellants. Figure 39 presents preliminary cost estimates for the transport mission. The total cost for both rocket propellants, at a mixture ratio of 7 to 1, is approximately 5¢ per pound as compared to 2¢ per pound for each pound of kerosene consumed by the aircraft engine. In terms of cost per seat-mile, considering only the specific fuel cost (when the vehicle cost is amortized over a large number of flights), ITHACUS would cost 27 times as much to operate than would a conventional jet aircraft.

Although cost of cryogenic propellants can be expected to reduce with mass production, it does not appear that it can conceivably be reduced to a competitive level with JP-4 fuels. Moreover, a ballistic trajectory, of the ITHACUS type, would consume far more propellant weight, for the same total range and payload, than would a conventional aircraft. This point is borne out by inspection of Figure 39. For example, seven DC-8F airplanes would carry a total payload equivalent to ITHACUS These seven aircraft would consume a total of 1.46 million pounds of JP-4 (at 2¢ per pound), as compared to ITHACUS which requires 12 million pounds of cryogenic propellants (at an average cost of 5¢ per pound).

GLOBAL TRANSPORT VS. AIRPLANE FUEL COST COMPARISON

	ITHACUS (LO_2/LH_2 7/1)	AIRCRAFT (JP-4 FUEL)		
	MIL TRANSPORT	C 133A	DC-8F	C 130A
RANGE - N MI	7600	7600	7600	7600
PAYLOAD - TONS (INCL STRUCT)	290	—	—	—
USEFUL PAYLOAD (TONS)	132	17.8	18.9	9.2
USABLE FUEL (LB)	12M	198K	208K	99K
FUEL COST ($/LB)	0.061	0.017	0.017	0.017
SPECIFIC FUEL COST ($/TON MILE)	0.612	0.025	0.026	0.024
NUMBER OF REFUELING STOPS	0	1	1	2
TROOP CAPACITY	1200	175	180	92
SPECIFIC FUEL COST ($/SEAT MILE)	0.0675	0.0025	0.0025	0.0024

ASSUMED PROPELLANT COSTS
JP-4 AT $0.11/GAL. ($0.02/LB) - LO_2 AT $0.02/LB - LH_2 AT $0.27/LB

FIGURE 39

Concluding Remarks

Clearly, the argument for a rocket-powered transport is not based on economy, nor is increased passenger comfort a realistic rationale; nevertheless, the same can be said for the SST. Yet, the insatiable demand for ever-increasing speed is providing the necessary impetus for development of the SST, although no pretense of improved economy is implied.

An ITHACUS-type vehicle would not be developed for the specific missions defined herein. Its mission potential must be examined within the proper context - as a possible extension of reusable booster technology. Only when the latter machine already exists, for satisfying space exploration requirements, will its adaptation for ballistic transport purposes appear warranted. Before the desirability of a ballistic transport can be established, its anology to "Operation Big Lift" must be reexamined. The 4.45 million pounds of total payload, transported during "Big Lift" which required 235 missions, could be performed with 17 ITHACUS missions. The 10 hours required for each airplane flight could be reduced to slightly more than an half-hour without refuelling - and each military mission could be undertaken with the complete assurance that a landing site would be in existence upon arrival at the destination. Nevertheless, the following fundamental questions remain to be resolved:

1. what is the military significance of transporting an entire battalion of troops in one vehicle
2. what price will we pay for drastically increased speeds and impressive reductions in flight time
3. how much is the added logistic flexibility worth when reliance on a landing strip is not required
4. what dollar value shall be assigned to an unlimited-range capability
5. how is the deterrent consequence appraised of a military arsenal which includes vehicles with the above capability

6. how can the value be assessed of the added, still unknown, benefits which are certain to be derived from further applications of reusable booster derivatives?

The ROMBUS antecent has been estimated to cost from 5 to 6 million dollars for development. How much can be saved by designing the ITHACUS version as a straightforward modification of a presumably existing vehicle, and to what extent would this cost reduction offset the unattractive operational cost-effectiveness of the ballistic transport?

In conclusion, it must be stated that approximately a billion dollars will be spent for development of the Supersonic Transport, purely for the sake of increased speed. Based on an estimated market of 40 to 80 airplanes, each SST would cost three to four times as much as today's commercial jet transport; yet, this fact is not hindering necessary progress in a vital technology.

Perhaps a smaller version of ITHACUS, related to a Saturn-class of reusable booster, would prove more attractive. A ballistic transport of this size could also function as a tourist carrier to earth orbit and return. The military ITHACUS size, as were many of its design features, was a direct result of its predecessor configuration, the ROMBUS reusable booster. Although the ITHACUS concept has been subjected to only a superficial analysis, it can be stated, with a high degree of confidence, that its technical feasibility has been completely verified.

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